Chapter 13
Design of Other Items

13-1. Galleries

A system of galleries, adits, chambers, and shafts is usually provided within the body of the concrete dam to furnish access and space for foundation drilling and grouting and for the installation, operation, and maintenance of equipment accessories and utilities in the dam. The primary considerations in arranging the required openings within the dam are personnel safety, functional usefulness and efficiency, and location of the openings with respect to maintaining the structural integrity of the structure.

a. Ventilation. In accordance with EM 385-1-1, all of the above-mentioned galleries and other associated features should be provided with adequate ventilation for safe operation, maintenance, and inspection. Adits should be equipped with doors of structural steel grillages that allow free circulation of air in and out of the galleries. This arrangement may be supplemented by using vent holes in the galleries and at other selected locations and by placing powered exhaust fans in special areas. Hydrogen sulfide gas in the galleries is a hazard to personnel. Ventilation equipment where this gas occurs must be explosion-proof.

b. Required dimensions. A gallery for the grouting of the foundation cutoff will extend the full length of the dam. It will also serve as a collection main for the seepage from the foundation drainage holes. See Figure 7-1. The location of the gallery should be near the upstream face of the dam and as near to the rock surface as structural design and layout will allow. It has been standard practice to provide grouting galleries 5 ft wide by 7 ft high. Experience indicates that increasing these dimensions can facilitate drilling and grouting operations. Where practicable, the width may be increased to 6 ft and the height to 8 ft. The floor of the gallery should slope about 1/4 in. per foot to a minimum-size 12-in. by 12-in. gutter along the upstream side. The depth of the gutter will vary so that the bottom slopes for proper water flow to the collection sump. The gallery is usually arranged as a series of horizontal runs and stair flights as dictated by the varying foundation levels. The stairs should be provided with safety treads or a nonslip aggregate finish. Where it is probable that equipment will be skidded up or down the steps, metal treads are preferable since they provide protection against damage to the concrete. Where practicable, the width of tread and height of riser should be uniform throughout all flights of stairs and should never change in any one flight. Details of drilling and grouting operations and equipment are covered in EM 1110-2-3506.

13-2. Machinery Platforms

a. Reinforced concrete. A reinforced concrete platform is readily adaptable for tainter gate hoist machinery support--especially for cases where the weight of the machinery and components plus the tainter gate and lifting cables creates a very heavy loading on the platform. The heavily reinforced concrete support members are cantilevered off the top of the pier. If a service bridge or walkway bridge is provided, the machinery base level and the bridge level will be at approximately the same elevation. A heavy structural steel frame, anchored to the concrete with embedded anchor and adjusting bolts, provides support for the machinery and components. Typically, a minimum of 1-in. cement grout is placed under the steel frame after it is adjusted to the proper location and elevation. The machinery and components are then bolted to the top of the frame. See Plate 20 for layout of a typical structural steel frame for the hoist machine and components it supports.

b. Steel grillage with concrete deck or grating. On smaller navigation dams where loads are not so large, a cantilevered structural steel support assembly may be more adaptable for use than a reinforced concrete support. The structural steel assembly is anchored to the top of the pier with embedded anchor and adjusting bolts. After the support is installed to line and grade using second-pour concrete, the machinery and components are bolted to the top of the support assembly. The openings in the support assembly are sometimes covered with steel grating so that personnel will have access to all components of the hoist machinery for maintenance, inspection, and repair activities.

c. Design loadings. In addition to its own dead weight and the weight of the hoist machinery and components, the cantilevered platform must be designed for the following loads: dead weight of the tainter gate, side seal friction, dead weight of wire ropes or chains, trunnion friction, silt and drift accumulation on gate, ice accumulation, impact, and stall torque of electric motor. See EM 1110-2-2702 for further information and guidance on hoist loadings.

13-3. Machinery Houses

a. Requirements and optional usage. In locations where climates are severe and the seasonal icing, rain, wind, and cold temperatures may interfere with and be a hindrance to operational and maintenance activities, the spillway gate operating machinery should be placed inside an enclosure. The use of a house with enough room to access all parts of the machinery is usually advisable. The house may be constructed of metal (steel or aluminum) or reinforced concrete. The reinforced concrete houses require less maintenance and can be designed to be more aesthetically pleasing than the metal houses. Adequate ventilation and electrical illumination will need to be provided. In warmer climates, the spillway gate machinery may either be enclosed by a metal cover or be left in the open air with no cover except for parts susceptible to weather damage. These parts can be covered by shrouds. The designer, in conjunction with operations personnel, will need to decide which of the above options is most desirable for a specific project. However, it is usually a good idea to have similar machinery treatment for all dam projects on the same waterway. A typical concrete machinery house is shown in Plate 20.

b. Design loading. When machinery houses are made of either metal or reinforced concrete, the design live loading due to wind, snow, and ice must be considered for the area where the project is located. The roof should be designed to withstand a live load of at least 30 psf over the entire roof area, plus the maximum live load expected on any overhead lifting hooks or traveling hoists attached to the roof ceiling. The thickness of the roof and walls of a reinforced concrete structure will usually be in the range of 6 to 8 in.

c. Requirements for machinery. For removal and maintenance access, all machinery houses must have removable panels with lifting attachments that can be handled by crane. Thus, the crane can lift off the removable panel and then lift out the heavy machinery, or any of its components, for extensive maintenance or repair. Where machinery covers are used in lieu of houses, lifting attachments will be necessary on the covers, so that a crane can lift off the entire cover should extensive maintenance or repair be necessary. Hinged panel openings should be provided on the equipment covers for normal inspection and maintenance activities. For ease of handling, equipment covers should be made of metal shrouds.

13-4. Line Hooks

Line hooks should be placed upstream and downstream at appropriate locations in the dam pier faces and adjacent lock wall faces for use in tying up the floating plant for maintenance and emergency activities. They are usually placed in a series, one directly above the other, about five feet apart starting a short distance above pool level. The line hooks are typically fabricated from 8-5/8-in. OD, 1-in.-thick wall steel tubing (ASTM A519, Grade 4130, condition SR) and filled with grout. Cast-iron or cast-steel hooks should not be used because it is becoming increasingly difficult to get quality castings. The line hook and anchorage should be designed for reactions resulting from a 160-kip line pull using normal allowable stresses. The arrangement should include a curved steel frame and anchorage reinforcement. See Figure 13-1 for line hooks details.

13-5. Check Posts

Check posts, suitable for use by the floating plant in tying up to the structures during maintenance and emergency activities, should be provided on the top surfaces of all piers both upstream and downstream. The check posts are typically fabricated from 8-5/8-in. OD, 1-in.-thick wall steel tubing, ASTM A519, Grade 4130, condition SR, and filled with grout. Cast iron or cast steel should not be used. Checks posts with embedment should be designed for a minimum line pull of 160 kips using normal allowable stresses. See Figure 13-2 for check post details.

13-6. Deadman Anchorage for Floating Plant

In case of uncontrolled flow through a spillway bay, because of blockage of the bay by a barge or other vessel or due to a machinery failure or gate malfunction, it is advisable to furnish a means for anchoring the floating plant above the dam. This can be accomplished by providing deadman anchorages on the banks above the dam and locating a check post(s) on the riverward side of the adjacent upper guide wall of the lock. The floating plant can then tie to these items and be reasonably stable for work in the flowing water to either place spillway bulkheads or remove the obstruction from the bay.

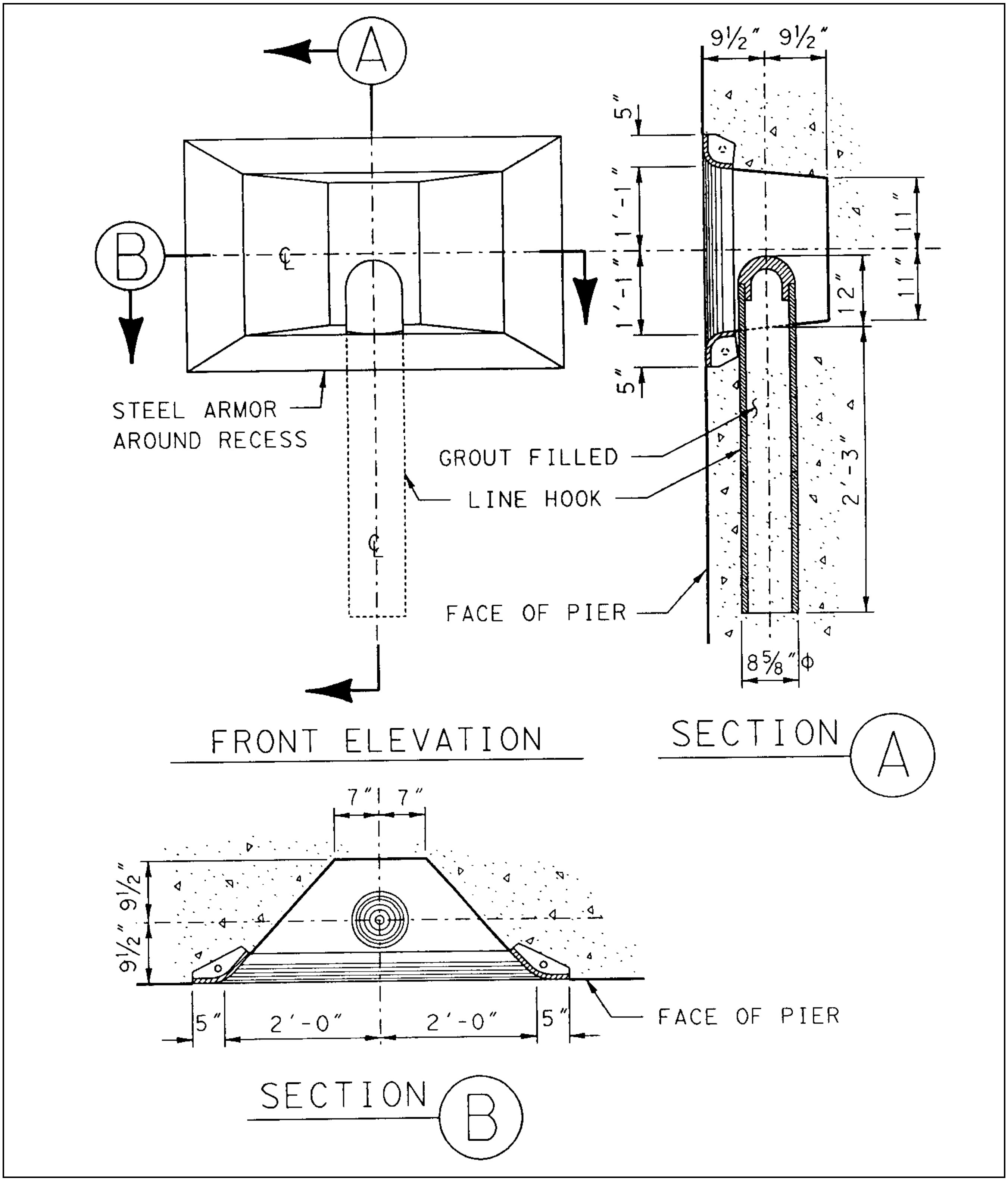

Figure 13-1. Line hook recess detail

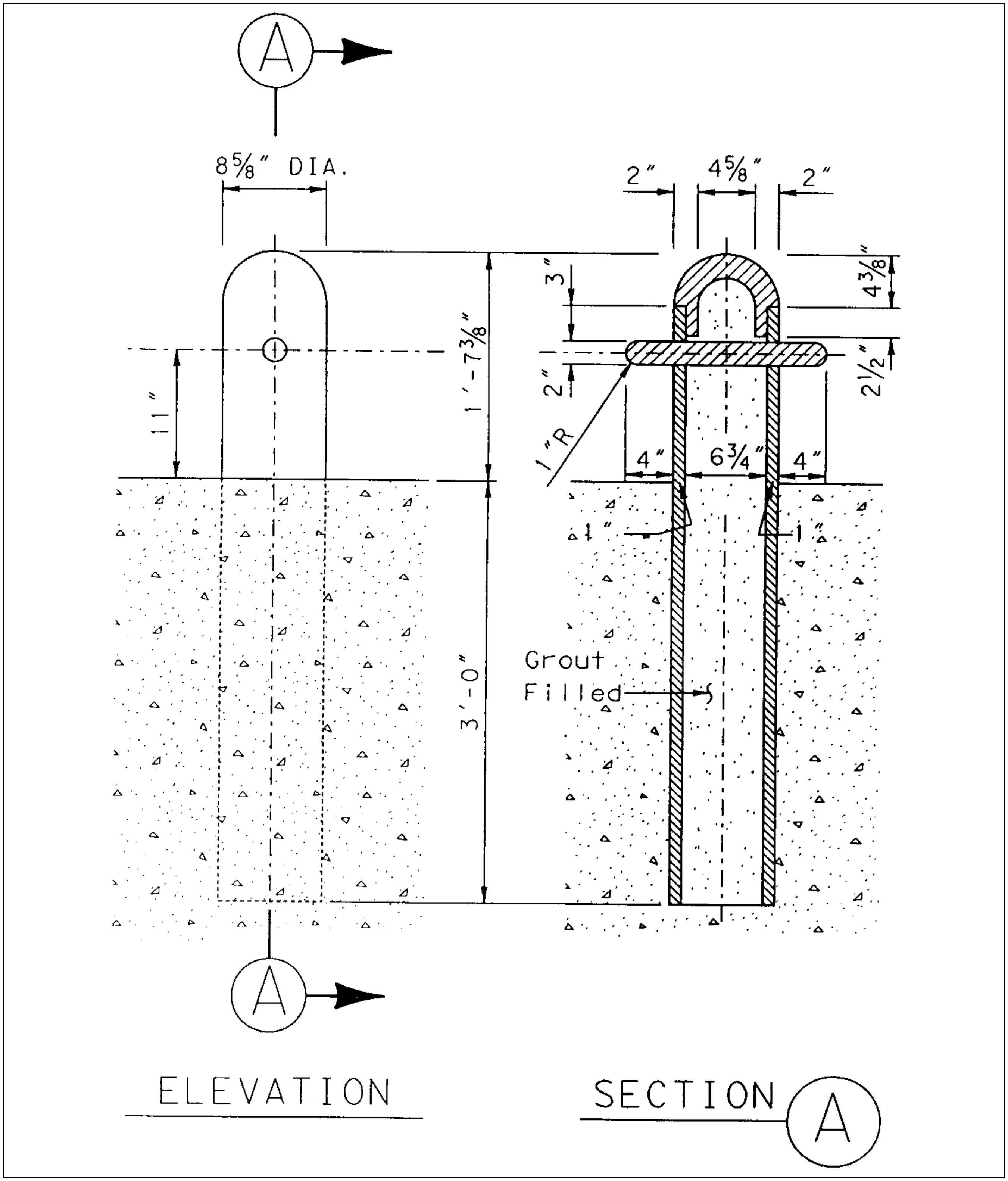

Figure 13-2. Check post detail

13-7. Ladders and Stairs

To provide safe and timely access for normal maintenance of and emergency attention to operating machinery and other important parts of the dam, permanent ladders or stairways should be provided in accordance with EM 385-1-1. Permanent ladders should be used only when the use of stairways is not practical or feasible. Stairs may be either concrete cast in place, precast concrete, or structural steel. Treads shall be provided with nonslip material at least at the nosing. Ramps, rather than stairs, may be provided when fewer than three risers are involved; the surfaces of such ramps should be covered with an abrasive material.

13-8. Access to Trunnion Area and Bulkhead Slots

Where practical, safe ladder or stair access should be provided to the top of all concrete trunnion girders whereby the tainter gate trunnion pin, yoke, and arms can be inspected and serviced. Piers will usually be wide enough to accommodate an interior stairway from the service bridge level down to a walkway opening on the downstream face of the pier for access to the top of the trunnion girder. Access to the lower part of the trunnion girder and prestressed anchorage covers will usually require a permanent ladder installation. Since the tops of the upstream bulkhead slots and bulkhead dogging devices are provided with a level walking surface, they can be accessed from this same interior stairway and another walkway opening. Access to the top of the downstream bulkhead recess may be possible only from the floating plant. However, permanently fixed ladders may be provided if practical.

13-9. Corner Protection

All bulkhead slots should be provided with structural steel corner protection on vertical upstream and downstream surfaces plus steel protection at the top of the slots. This will prevent damage to the slots due to bulkhead installation activities and from flowing water and the material that it carries. If vertical-lift spillway gates are used, the necessary recesses in the piers will also require similar corner protection. Corner protection may also be required at other locations depending on whether or not they are involved with maintenance or operational activities, subject to flowing water, or other potentially damaging situations.

13-10. Handrail and Guardrail

Permanently fixed handrails and guardrails should be provided, in accordance with EM 385-1-1, at all locations on a dam structure where safety and operational needs dictate their necessity, including the top deck of service bridges; the tops of concrete trunnion girders; stairways, inside or on sides of piers; walkway surfaces on piers, especially at the tops of bulkhead slots; and around vertical access shafts and ladder recesses and the arms of large tainter gates. Galvanized steel, aluminum, or painted steel handrails and guardrails may be selected for use. Anodized aluminum rails and posts will require a larger pipe diameter than steel, to meet strength criteria. Also, the strength reduction effects of welding must be considered in computing the required size of aluminum rails and posts.

13-11. Parapet Walls

Where conditions on a dam are such that concrete parapet walls are more desirable than handrails and guardrails, reinforced concrete parapet walls may be used as shown in Figure 13-3. The height of the wall should be the same as that of the metal rail, and the concrete thickness should be at least 8 to 12 in., with proper top slopes and possible aesthetic treatment.

13-12. Grating

Recesses, access shafts, catwalks, machinery platforms, and pits in the dam piers and at other locations in the dam should be provided with covers. Usually, galvanized steel grating is provided if grating is to be manually removed. In some cases, it may be necessary to cover the grating with steel plate for safety purposes.

13-13. Service Bridges

a. General. Service bridges provide support for overhead cranes and/or provide access to mechanical equipment located on the dam structure. Typically, traveling hoist cars or gantry cranes transport emergency bulkheads or vertical-lift gates to each gate bay and in some cases the navigation lock. The crane may also have an auxiliary crane attached for use in maintenance operations. A typical hoist car with auxiliary crane, supported by a service bridge, is shown in Plate 9. Plate 13 shows a cross section of a spillway service bridge for the gantry crane at John Day Dam on the Columbia River. A smaller service bridge which serves as a personnel walkway is shown in Plates 1 and 2. Plate 11 shows a vehicle access bridge across the dam spillways at Lock and Dam “D” on the Tennessee-Tombigbee Waterway.

b. Service bridge superstructure.

(1) For some of the larger dam projects on the Ohio and Mississippi Rivers, the service bridge usually consists of a concrete deck and up to three simply supported American Association of State Highway and Transportation Officials (AASHTO)- type precast, prestressed girders (beneath each crane rail) that act as a composite system. The crane rail is centered on the middle girder. The clear opening between the upstream and downstream girder assemblies allows passage of the crane cab and transport of the bulkheads between the girders when the service bridge also serves the lock chamber. The bottom elevation of the girders is selected to allow a specified clearance above maximum operating upper pool for navigation through the lock. This specified clearance will usually be available from the U.S. Coast Guard and is the same clearance as is required for the low steel of railway and highway bridges which cross the waterway.

(2) Plate 5 shows a plan view of a service bridge that serves both the dam spillways and the lock chambers at the Melvin Price project on the Mississippi River. Plate 6 shows a cross section of this same service bridge. Plate 8 shows a cross section of a similar service bridge installation at Smithland Locks and Dam on the Ohio River.

c. Service bridge substructure. The service bridge substructure is provided by the dam piers and piers located on the navigation lock walls. Reinforced elastomeric bearing pads or rocker-type assemblies are recommended for bridge bearings. Cable restraints and concrete shear blocks should be provided to enable positive means of anchoring the superstructure to the substructure for seismic loads.

d. Crane rails. The service bridge crane rails should be sized to fit the crane wheel flanges. The 175#-per-yard American Railway Engineering Association (AREA) rail has been found suitable for projects having heavy hoist cars that travel with heavy sectional bulkheads and lower several sections latched together onto the spillway sill. The base of the rail should rest on heavy bearing plates at the service bridge deck level with embedded anchor bolts and levelling nuts for setting the crane rail to the proper elevation. A continuous plate may be required to reduce concrete bearing stresses to an acceptable level. These anchor bolts should extend through this plate and through rail clips which anchor the rail in place. Careful attention should be given to sizing, detailing, and locating the expansion and contraction joints in the rail, and to corrosion mitigation of embedded anchor bolts. Standard AREA splice bars should be used at all rail splice locations. Bituminous material can be used to cover the rail splice bars and the protruding anchor bolt heads and clips. Care must be taken to ensure against water being trapped and corroding plate anchor bolts. Details of the rail splices and rail anchorage assembly without bituminous coverings are shown in Figure 13-4.

13-14. Structural Instrumentation

Instrumentation for securing structural data in a dam structure may yield the following information: uplift pressures, concrete monolith tilt or differential movement, steel sheet pile cell interlock tension or cell movement, anchorage tendon or rod tension stress retention, concrete crack width increase, pore pressure, interior concrete temperature, leakage, and alignment monumentation observations. EM 1110-2-4300 provides adequate coverage and guidance for most of the required structural instrumentation.

13-15. Warning Signs

Signs reading “Danger-Stay-Away,” or “DANGER-STAY _____ FEET-AWAY-FROM-DAM,” or some other appropriate message should be mounted on the upstream and downstream handrail (or parapet) of the dam service bridge in the middle of the spillway and facing toward the upper and lower pools. Both the frame for the signs and the background for the letters should be of steel material designed to withstand a minimum of 30-lb/sq-ft wind pressure. The lettering should be a red color with a contrasting background and the individual letters should be 24 in. high or more and approximately 12 in. wide so that the sign can be read by a person with normal vision from a safe distance suitable for the specific project conditions. The signs should have adequate lighting so they can be easily read at night from this same distance. Refer to ER 1130-2-306.

13-16. Embedded Metals

a. General. Certain navigation dam steel structures will require embedded metals that should be installed in second-pour blockouts. Use of the second placement procedure allows for proper positioning of the embedded item at the designated grade and alignment for proper functioning of the companion structure. See Plate 19 for

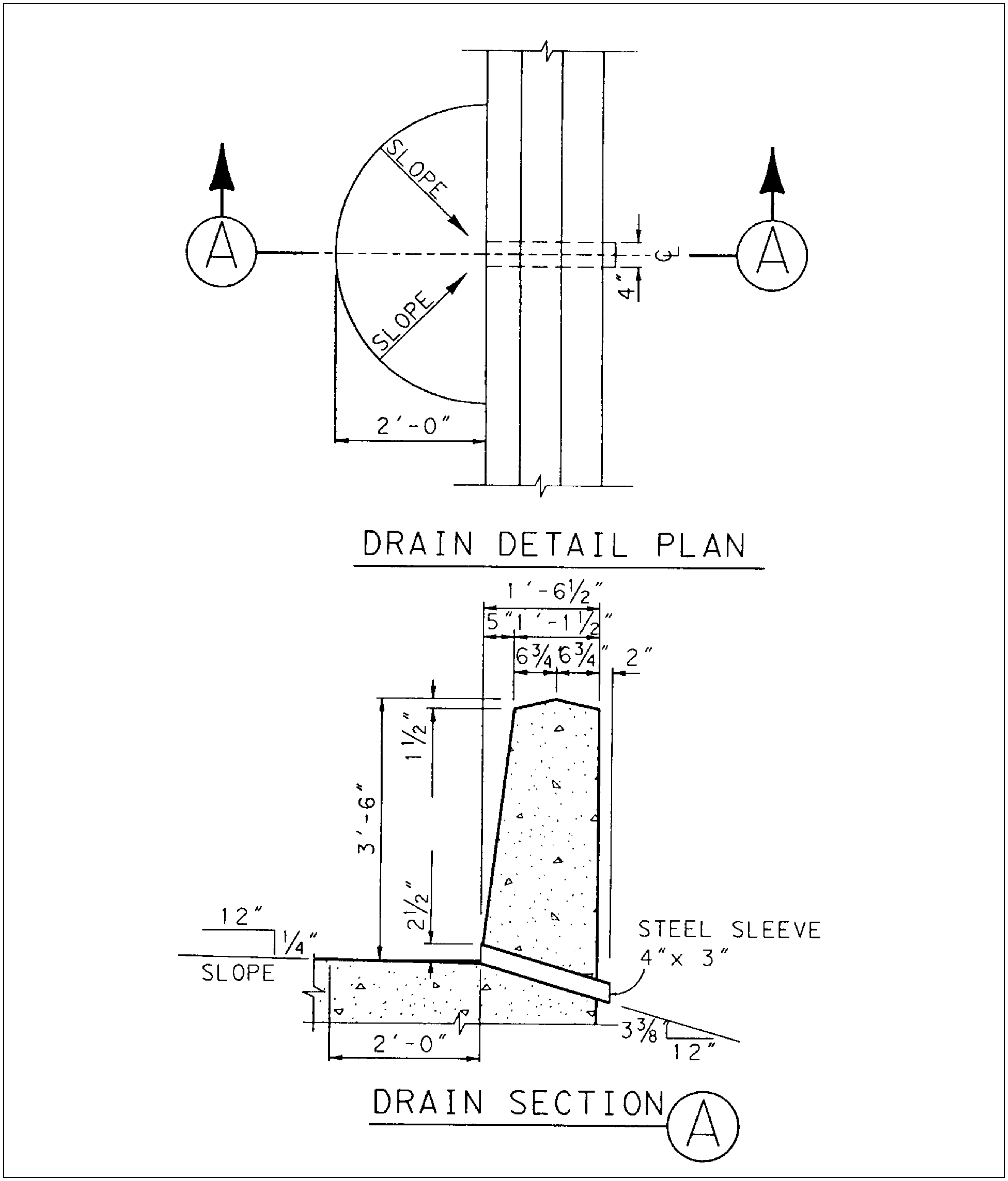

Figure 13-3. Concrete parapet detail

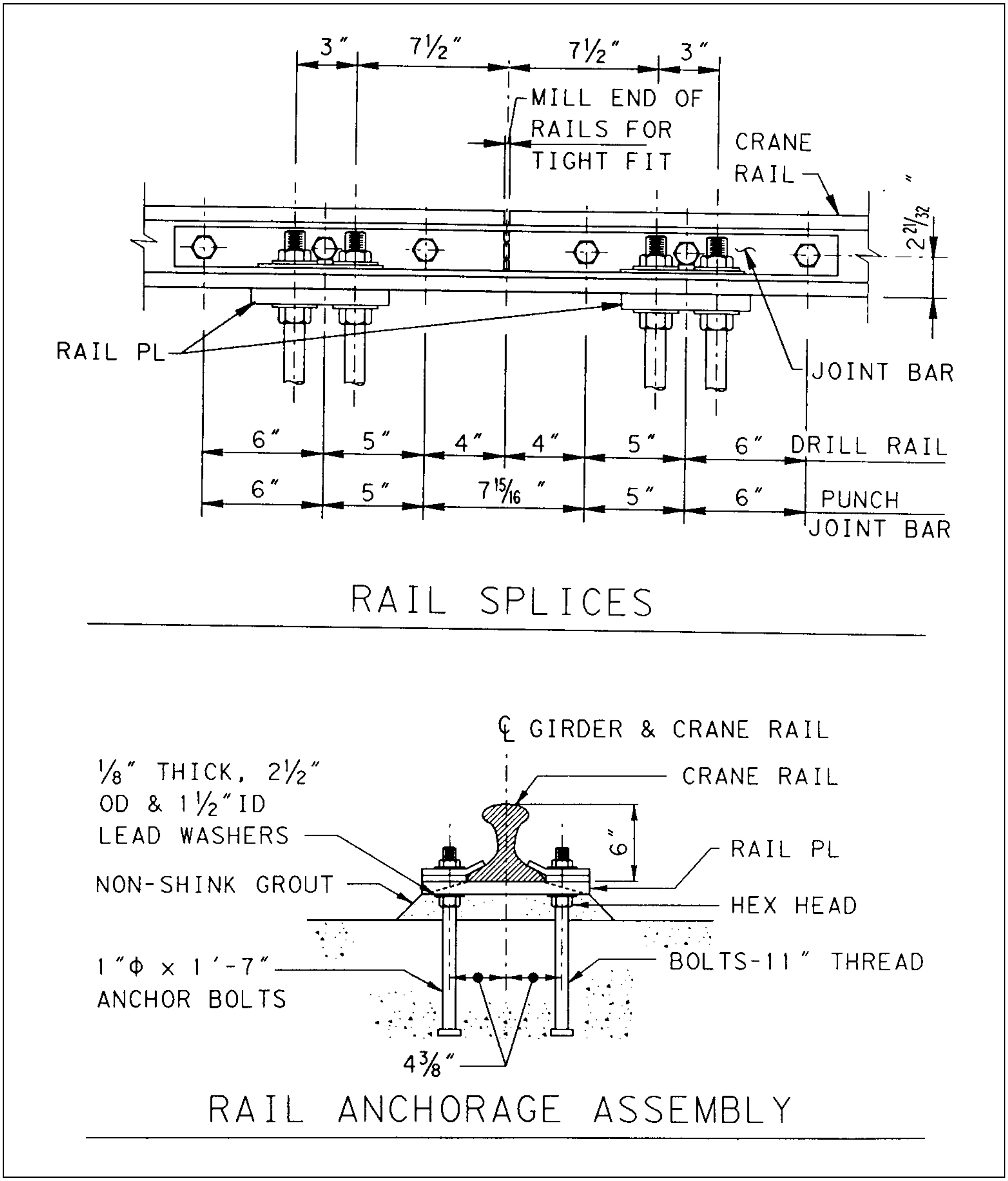

Figure 13-4. Rail anchorage assembly

typical embedded structural steel members with anchorages and adjustment bolts.

b. Embedded items and function. The primary embedded structural steel items and their usage are as follows.

(1) A curved side seal and rubbing plate are used with rubber "J" seal mounted on each side of spillway tainter gate.

(2) A continuous sill beam serves as level seating and metal-to-metal sealing surface for spillway gates--tainter, vertical-lift, or roller--and spillway bulkheads.

(3) Individual sill bearing plates serve as level seating surfaces for spillway bulkheads.

(4) Recess (slot) armor plates, bearing plates, seal plates, and guide plates for vertical-lift spillway gates and spillway bulkheads serve as true vertical bearing surfaces to transfer gate or bulkhead water load to concrete; serve to seal in conjunction with rubber "J" seal on each end of gate or bulkhead; serve to protect concrete in and adjacent to the gate or bulkhead recesses (slots) from damage during installation and removal activities; and serve as contact rolling and positioning surfaces.

(5) The trunnion anchorage assembly is used with prestressed concrete trunnion girders for tainter gates.

(6) The gate hoist machinery frame (exposed frame with embedded anchor and adjusting bolts and grout support) serves as a level base and support for hoist machinery and components.

(7) Service bridge embedded metals include crane rail anchorage and hand rail anchorage.

(8) Other miscellaneous embedded steel items are used for bulkhead dogging devices, concrete corner protection, grating supports, handrail supports, stair treads, ladder supports, tainter gate stops, and mooring rings and check posts.

c. Material. The most durable and long-lasting materials must be chosen for embedded metals--especially for metals that are continuously submerged--such as anchor bolts and nuts, horizontal seal and sill plates, curved and vertical seal and bearing plates, recess (slot) armor and guide plates, wicket gate components, drum gate components, hinged-crest gate components, etc. Embedded items whose surfaces serve only for armoring protection and/or positioning purposes can be made of ASTM A-36 steel and painted, whether exposed or submerged. The embedded portions of steel items are never painted. However, the embedded portions need thorough cleaning to remove mill scale, rust, and dirt prior to concrete placement. This will help to ensure a good bond of the steel and concrete. Aluminum must not be embedded in concrete without some sort of separation coating, such as bitumastic, on the embedded portion. Embedded items with surfaces that serve as rubbing surfaces, guide surfaces, seal surfaces, or bearing surfaces, whether exposed or submerged, must be made of either solid stainless steel or clad stainless steel.

13-17. Mechanical and Electrical Features

a. General. This section will provide a broad overview of mechanical and electrical equipment with a brief description of the functions of the various items.

b. Mechanical and electrical. The major mechanical and electrical features for a navigation dam include the following:

(1) Hoist machinery for spillway gates. As an example, the gate hoists for a tainter gate will consist of two fixed units, one at each end of the gate, located near the top of the piers. These units will be driven by one electric motor mounted on one of the units. The drive unit and the driven unit will be coupled together by a line shaft or a torque tube extending between the two units. The drive side will have the electric motor, two bull gears, speed reducers, cable drum, and a brake. The driven side will have two bull gears, speed reducers, and a cable drum or chain rack. All these items will be mounted on a structural steel frame. The electric motor horsepower required will be determined by the requirements of EM 1110-2-2702. The operation of the individual gate hoist motors will be controlled by a pushbutton-type master control station located near each drive unit. Remote operation of the hoists can also be provided. For complete details of hoist mechanical and electrical features, see EM-1110-2-2702. See Plate 20 for a typical layout of hoist machinery. In Europe, gates are raised or lowered with hydraulic cylinders instead of cables. This type of design should be considered.

(2) Operating machinery for wicket gates and hinged-crest gates. Typical machinery will usually be hydraulic and will consist of a hydraulic power unit, hydraulic cylinder, operating rod, linkage to structure, and torque tube. One hydraulic pump may serve one or more cylinders with valving that would allow directing pressure

to other cylinders in the system. The Olmsted wicket dam on the lower Ohio River is an example of this type of hydraulic system. Dam No. 3 on the Red River in Louisiana has a single hinged-crest gate, which is operated by a hydraulic cylinder arrangement at each end. Electric power must be provided to all hydraulic pumps.

(3) Traveling gantry crane. Traveling gantry cranes are sometimes used for installing and removing vertical spillway gates, vertical bulkheads, and sectional bulkheads. Necessary electric power is supplied to the gantry crane by either power takeoff rails or a retractable power cable on a reel. Procurement of this crane will be by a dimensional requirement drawing and a performance specification.

(4) Traveling hoist car. The traveling hoist car is used for transporting, installing, and removing spillway sectional bulkheads. Electric power is supplied to the hoist car via power takeoff rails. Procurement is by the same method as for the gantry crane.

(5) Sluice gates and operators. Operators may be needed for raising and lowering sluice gates. A limited number of sluice gates are used on navigation dams. When they are provided, they will be used for minimum-flow water quality releases, discharges to attract fish, or drawdown of the reservoir in an emergency situation. Electric motors are used for operating power. Some large sluice gates will be hydraulically operated. Also, large sluice gates are usually installed in pairs on a single conduit for operational safety, inspection, and maintenance purposes. Upstream bulkhead slots may also be provided.

(6) Sump pumps. Sump pumps are used for pumping water from the drainage gallery sump and discharging the water into the lower pool.

c. Effects on concrete structures. The above items influence the concrete structure layout and design requirements in a variety of ways.

(1) A tall pier is required for the spillway gate hoist machinery in order to operate the gate through its designed range of travel. Also, it is desirable to provide a machinery house or cover in certain cold climates. The line shaft connecting the hoist machinery on adjacent piers can often be supported by brackets or cantilevered steel members fastened to the service bridge or to catwalk framing. If the layout is not suitable for this arrangement, a self-supporting torque tube must be used in lieu of the line shaft.

(2) The wicket gate operating machinery needs to be located in a watertight gallery. The hinged-crest gate machinery needs special support and operating space at each end of the gate for housing of hydraulic cylinders and crank mechanisms.

(3) Both the traveling gantry crane and traveling hoist car need a high service bridge with crane rails to travel on for performing spillway gate and bulkhead installation and removal procedures.

(4) The sluice gates and operators require a water-carrying conduit through the dam. Also required are sluice gate access galleries, operating rooms, shafts, and a bulkhead shaft extending to the top of the dam.

(5) The gallery pumping system must have gutters in the drainage gallery which collect and direct water to a sump pit adjacent to the gallery room containing the pump. There must also be a pump discharge pipe to the lower pool.

13-18. Catwalks

Structural steel personnel catwalks will need to be provided on navigation dams when there is no other practical means of access to project features that require periodic inspection, adjustment, greasing, painting, or other maintenance as well as possible replacement. Galvanized steel framing, handrail, and grating will normally be used. Design live loading should be at least 100 lb/sq ft with localized loads of the heaviest equipment or machinery expected possible on the structure.

13-19. Dam Lighting

Lighting facilities need to be provided for use by operating personnel and maintenance, inspection, and emergency crews, and for the benefit of navigation interests. Lighting will be required for the following areas: stairwells in bridge piers, galleries and access shafts, service bridge roadway, piers (exterior), machinery house interiors, spillway gate bays, crane and hoist cabs, fixed weir, signal lights, and warning signs. Reference ER 1130-2-306 and EM 385-1-1. Enclosed spaces such as stairwells, galleries, access shafts, crane and hoist cabs, and machinery houses need to have good lighting for use by operating, inspection, and maintenance personnel. Switches should be conveniently located and readily available at adits so as not to have to be searched for in the dark. Some type of additional low-level emergency lighting could be considered for galleries. Service bridge roadway lighting can be pole-mounted on the machinery house at each pier. If a machinery house is not used at the service bridge roadway level, the lighting can be mounted either on the roadway guardrail or on poles. Exterior pier lighting will include upstream and downstream floodlights and floodlights on each pier face for lighting the spillway bays. Upstream and downstream signal lights should be mounted as high as possible on the dam structure. The number required will depend on the specific project layout. Upstream- and downstream-oriented searchlights should be mounted high on the piers or bridge roadways at locations readily accessible to operating personnel. The number required will depend on the specific project requirements. Some navigation dams have fixed overflow weirs which need to have some lighting. This can be achieved by a floodlight on the face of the adjacent pier at one end and a pole-mounted floodlight at the other end.

13-20. Lightning Arrestor System

A sufficient-size grounding cable should be provided to connect all machinery, electrical apparatus, conduits, conduit supports, crane rails, hand railing, spot and floodlights, lighting standards, and all extensive exposed metal items to a ground mat or ground rods for protection of equipment and personnel. Some projects have also provided for protection of the dam and its metal features from potential direct lightning strikes. The lightning protection system is composed of several tall poles located on the highest point of the dam structure and connected by metal cables which are tied into the above grounding system. This type of lightning protection system was used on some of the Red River Waterway projects in Louisiana.

13-21. Cathodic Protection

All major structural steel structures which are submerged need to be provided with cathodic protection such as sacrificial anodes or the impressed current type to prevent corrosion. Submerged recess armoring, bearing plates, seal plates, etc., need to have cathodic protection when they are composed of dissimilar metals--stainless steel in combination with carbon steel, for example. When steel sheet piling is used as part of a fixed weir or other permanent structure, some type of protection should be provided at the water line, where the piling is constantly subjected to wetting and drying due to wave action. Some height of this piling, above and below the water line, should have corrosion protection. If cathodic protection is not used, then a durable coating such as bitumastic or an increased steel thickness should be used.

13-22. Surveillance Systems

Television transmitters with appropriately located television screens (receivers) should be provided on dams so that the facility may be operated safely and efficiently. In planning surveillance systems, the designer should consult persons with experience and expertise in this technology--especially the latest state-of-the-art equipment available. For convenience of maintenance, the equipment chosen should be of standard types and reliable design. Choosing similar standardized equipment for all dams in a navigation system will allow for interchange of parts and equipment and reduce the supply of spare parts and equipment required in inventory. Television surveillance is especially useful in cases of remote operation of the spillway gates when recreational boats and fishing boats are likely to be in the water either upstream or downstream of the dam. Television surveillance will usually be supplemented by warning sirens or horns plus warning signs.

13-23. Waterstops

Waterstops prevent the migration of water through joints of dams. A double line of waterstops should be provided near the upstream face of the dam at all joints. For gated spillway sections the tops of waterstops should terminate at gate sills and tie in to embedded steel if provided. If a sheetpile cutoff is provided below the monolith, the waterstop should tie in to the sheetpile at monolith joints. A single line of waterstops should be placed around all galleries and other openings crossing monolith joints. Further guidance in the selection and use of waterstops can be found in EM 1110-2-2102.

13-24. Joint Materials

Dam structures are subject to volume changes due to temperature, moisture content, and chemical reaction. Adjacent monoliths may experience differential movement at joints due to exterior loading. To minimize these effects and preserve the integrity and serviceability of the structure, joints should be provided. The introduction of joints creates openings which must be sealed. Typical joint filler materials consist of a variety of substances and configurations, depending on the purpose of the filler. Detailed guidance in the selection and use of joint material can be found in EM 1110-2-2102.